Respiratory Physiology I

1. **What is the partial pressure of oxygen in inspired air?**

The concentration of a gas is multiplied by the total pressure. Dry air has 21% oxygen concentration. Total pressure at sea level is 760mmHg, so the partial pressure of oxygen is 159mmHg. Air in the airways is humidified with a water vapour pressure of 47mmHg, so the total dry gas pressure is only 713mmHg, so the oxygen partial pressure is 149mmHg

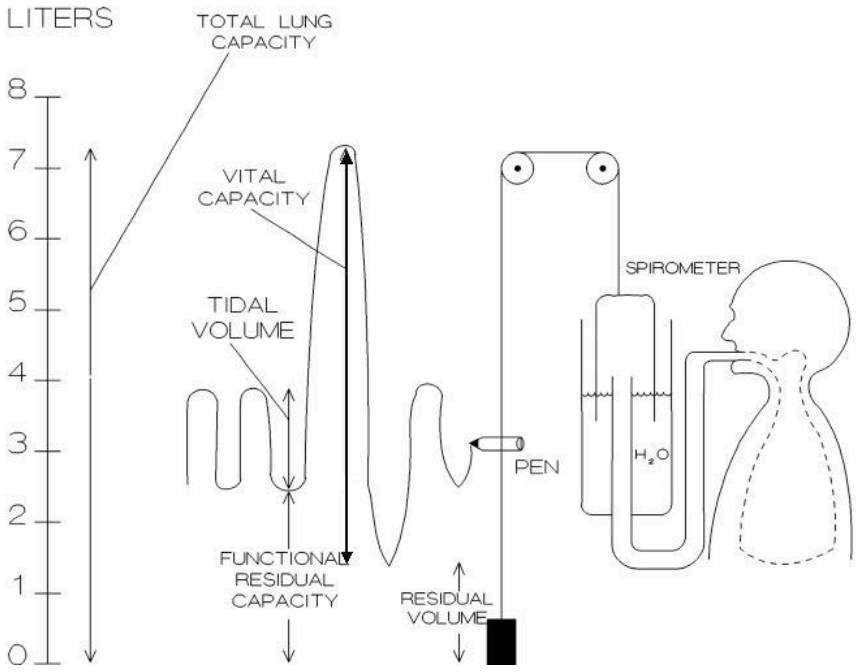
2. **What is Fick's Law of diffusion? What determines the diffusion constant?**

The amount of gas that moves across a sheet of tissue is proportional to the area of the sheet but inversely proportional to its thickness. In addition, the rate of transfer is proportional to a diffusion constant which depends on the properties of the tissue and the particular gas. The constant is proportional to the solubility of the gas and inversely proportional to the square root of the molecular weight. This means that CO_2 diffuses about 20 times more rapidly than O_2 through tissue sheets since it has a much higher solubility but not a very different molecular weight.

3. **What meant by anatomical dead space in the airways?**

Trachea to terminal bronchioles are conducting airways and play no part in gas exchange, the volume is ~150mL.

4. **Draw a diagram of lung volumes.**



5. **Describe both flow-limited and diffusion-limited gas transfer?**

The membrane is composed of the pulmonary epithelium, the capillary endothelium and their fused basement membranes. Blood has 0.75 sec to pass through. Whether equilibration occurs depends on how avidly it is taken up by Hb.
N2O is not taken up by Hb, so reaches its equilibrium quickly – 0.1s, so the amount of N2O taken up is purely limited by blood flow. In contrast, CO is taken up avidly by Hb, so doesn't reach equilibrium in the blood – the amount taken up is limited by its ability to diffuse across the membrane. Oxygen is in between the two, and reaches equilibrium in 0.3s in health.

6. **Describe oxygen uptake along the pulmonary capillary**

PO2 in a red blood cell enters the capillary is normally ~40mmHg. The alveolar pO2 is 100mmHg. Oxygen flows down this large pressure gradient and the pO2 in the red cell rapidly rises, very nearly reaching 100mmHg in a third of the total time (0.75 seconds) spent in the capillary.

In exercise, blood flow is faster, and the red cell might only have a third of the time in the capillary, but in health this should suffice.

With disease, the membrane can be thickened, impeding diffusion and the rate of rise of O2 is slowed and may not be completed, particular with exercise.

Reducing the inspired oxygen concentration (eg. with altitude) reduces the partial pressure difference and so diffusion occurs at a slower rate.

7. **What are the pressures in the pulmonary circulation?**

Systolic pressures around 25mmHg and diastolic pressures around 8mmHg. The lung is required to accept the whole of cardiac output at all times. Arterial pressure is as low as is consistent with lifting blood to the top of the lung, keeping the work of the right heart as small as possible for gas exchange to occur in the lungs.

8. **Describe the distribution of blood flow lungs.**

In the upright lung, blood flow decreases linearly from bottom to top.
The supine lung has equal distribution for apex to base, but the dependent regions have much greater flow that higher regions. With exercise, blood flow throughout increases and the gradient between upper and lower portions decreases.

Peripheral parts of the acinus may receive less blood flow, and peripheral parts of the lungs as a whole may receive less blood flow.

9. **Describe the difference of ventilation in different regions of the lungs**

The lower regions of the lungs ventilate better that the upper zones.

10. **What active mechanisms are there to control distribution of pulmonary blood flow?**

Hypoxic pulmonary vasoconstriction occurs when a reduction in pO2 of the alveolar gas causes contraction of smooth muscle in the walls of the small arterioles in the region. The mechanism is not known but is a local rather than central mechanism.

This has the effect of redirecting blood flow away from hypoxic regions of the lungs.

11. **What are some of the metabolic functions of the lungs?**

Synthesis of surfactant proteins
Protein synthesis – collagen and elastin
Elaboration of mucopolysaccharides of bronchial mucus.

Converts angiotensin I to angiotensin II by ACE
ACE also inactivates bradykinin
Removes serotonin by uptake and storage
Removes some noradrenaline
Removes prostaglandin E2 and F2alpha by enzymes
Removes leukotrienes

Secretes IgA in bronchial mucus

12. **What determines alveolar pO2?**

pO2 of alveolar gas is determined by a balance between two processes – the removal of O2 by pulmonary capillary blood and its continual replenishment by alveolar ventilation. The rate of removal of O2 from the lung is governed by the O2 consumption by the tissues. Alveolar gas usually has a pO2 of ~100mmHg.

13. **What is the relationship between alveolar ventilation and arterial pCO2?**

$$pCO2 = \frac{CO2\ production}{Alveolar\ ventilation} \times K$$

This shows that if alveolar ventilation is halved, the pCO2 is doubled.

14. What is the alveolar gas equation?

It shows the relationship between the fall in pO2 and the rise in pCO2 if we know the composition of inspired gas and the respiratory exchange ratio (respiratory quotient – determined by how much CO2 is produced for a given amount of oxygen, varies with carbohydrate Vs. protein consumption, but generally accepted as being 0.8).

P_{AO_2} can also be calculated from the **alveolar gas equation:**

$$P_{AO_2} = P_{IO_2} - P_{ACO_2}\left(F_{IO_2} + \frac{1 - F_{IO_2}}{R}\right)$$

A useful approximation is

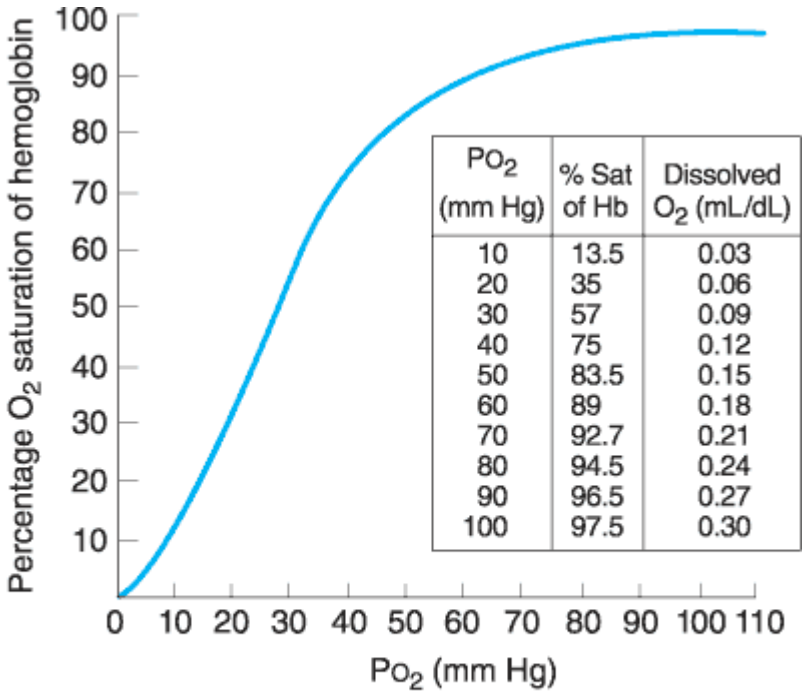
$$\text{Alveolar } pO_2 = \text{Inspired } pO_2 - \frac{pCO_2}{R}$$

where F_{IO_2} is the fraction of O_2 molecules in the dry gas, P_{IO_2} is the inspired P_{O_2}, and R is the respiratory exchange ratio, i.e., the flow of CO_2 molecules across the alveolar membrane per minute divided by the flow of O_2 molecules across the membrane per minute.

15. In health, is alveolar pO2 the same as arterial pO2?

Arterial pO2 is always slightly lower than alveolar pO2 for the following reasons.
Diffusion is never completely complete.
Shunted blood enters the arterial system without going through the ventilated areas of lung. Normally, some of the bronchial artery blood is collected by the pulmonary veins after it has perfused the bronchi and its pO2 is partly depleted. A small amount of coronary venous blood drains directly into the cavity of the left ventricle. In some heart disease, there may be direct addition of venous blood between right and left sides of the heart.

16. What is the oxygen dissociation curve?



PO_2 (mm Hg)	% Sat of Hb	Dissolved O_2 (mL/dL)
10	13.5	0.03
20	35	0.06
30	57	0.09
40	75	0.12
50	83.5	0.15
60	89	0.18
70	92.7	0.21
80	94.5	0.24
90	96.5	0.27
100	97.5	0.30

Rightward shift means more unloading of O2 at a given pO2. The curve is shift to the right by acidosis, pCO2, temperature and the concentration of 2,3 DPG in the red cells. An exercising muscle is acidic, hypercarbic and hot, and benefist from more O2.